Temporal Behaviour of Marine Landings Along Coastal Karnataka. I. Relative Distribution and Secular Trends*

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Landing data of 21 fisheries from Karnataka (quarterly landings for the period 1956 to 1978 and annual landings for the period 1979 to 1981) were analysed to study the temporal behaviour of the landings. The relative distribution and secular trends in each of the fisheries are reported. On an average, mackerel and oil sardine together account for about 70% of the annual landings. The fluctuation in the landings in all the fisheries was very high with the coefficient of variation attaining a minimum value of 61.53%. The inverse relationship between the landings of oil sardine and mackerel was found to be statistically significant. It is suggested that fishing effort be further increased in fisheries that have demonstrated a rising trend (about 73% of the total annual landings) as also in the case of the fisheries whose trends appear stagnant (about 21% of the annual landings). However, there seems to be some evidence of a need for regulating fishing in *Hemirhamphus* and *Belone*, *Caranx* and penaeid prawns. Regulations need to be made authentic with the help of sufficient information on not merely the fishery but on the whole population.

Analysis of fishery statistic is an important aspect of fisheries research. Apart from understanding the trend of past exploitation, it is important to develop models that assist in prediction. Models based on empirical data can also be used to detect seasonal and cyclical patterns in the availability of fish stocks. The detection of patterns that are unrelated to fishing effort would also provide tangible evidence of the influence of environmental and biological factors in governing the availability of fish stocks.

Considerable information is available in the literature on various commercially important groups of Indian fishes (Rao, 1973; Sekharan *et al*, 1973; Banerji, 1973a, b; Banerji & Krishnan, 1973; Kutty, 1972; Chakraborty, 1973; Chacko, 1973; Raja & Philipose, 1975 and Sastri, 1977, 1978). In most of these studies however, the trends have been obtained using data without accounting for seasonal, cyclical and random fluctuations. It would be of great use to the planner to have an accurate picture of the secular trend in the landings of a fishery, undisturbed by any other fluctuations. The present study was therefore taken up to decompose fish catch data over the years into time series components comprising of secular trend, seasonal patterns and cyclical oscillations.

Materials and Methods

Quarterly marine catch statistics in metric tonnes for coastal Karnataka (12°44′N to 14°53′N) were obtained from the Central Marine Fisheries Research Institute, Cochin for the period 1956 to 1978, for 'Total' landings as well as individual figures for 21 species/groups. However, data for the period 1956-'59 were available only for eight fisheries. Annual catch statistics for the above 21 fisheries for the period 1979–'81 were obtained from CMFRI (1982).

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Relative distribution

The relative distributions of the various fisheries are given as percentages of the aggregate landings of each year. The aggregate landings however, are not the actual total for each year (which is the sum of all the species/groups including those not listed in this paper, and which we refer to here as 'Total'), but the sum of the 21 species/groups of fishes being considered in this study. These fisheries represented on an average 90.5% of the annual landings. The 'Miscellaneous' group which represented on an average, 7.55% of the annual landings, was not analysed since its composition was not assumed to be constant. The rest of the species/group, representing 1.95% of the annual landings on an average, was not analysed since continuous data were not available. In order to present annual data, the quarterly data for the period 1956/60 to 1978 were pooled for each fishery.

Secular trends

The identification of the time-series components (only the secular trend is considered in this paper) calls for the decomposition of the data by suitable statistical methods. The decomposition of the time-series data into its components was carried out by assuming a multiplicative model which is expected to fit such data better than an additive model (Croxton *et al.,* 1967). Under the multiplicative model, an observation O_t (fish catch) 'pertaining to a specific time point 't', is a result of four influences, namely a trend effect (T_t), a seasonal effect (S_t), a cyclical effect (C_t) and a random (irregular) component (I_t), conceived mathematically in a multiplicative form, namely,

$$O_t = T_t \cdot C_t \cdot S_t \cdot I_t$$

These four components were estimated from the data on fish landings by standard methods (Croxton *et al.,* 1967). The seasonal indices were estimated first, using which the original observations O_t were deseasonalised by dividing by S_t to give the final estimate of TCI. These estimates (TCI's) were then plotted on a graph against time to check if any periodic (cyclical) pattern was discernible visually. Wherever an oscillatory pattern was suggestive, a centered moving average of an appropriate period was worked out to eliminate this cyclical component, leaving only T. The T values thus obtained and constituting the trend of the species/group under consideration, were then plotted on a graph. Wherever found suitable, these patterns were defined by appropriate mathematical expression. In the absence of any oscillatory behaviour, the deseasonalised data itself constituted the secular trend of the fishery, and has been presented as such.

Results and Discussion

Relative distribution

It is interesting to compare the relative distributions of the various fisheries. The year-wise percentage distributions of mackerel, oil sardine and penaeid prawns (the three largest in terms of average annual landings) as well as the sum of the remaining 18 species/groups are presented in Fig. 1.

Table 1. *Mean standard deviation and percent coefficient of variation of the annual relative (percentage) distribution of the landings of 21 marine fisheries of Karnataka*

Fishery	Mean	SO	%C.V.
Mackerel	36.2	23.54	63.85
Oil sardine	32.8	22.58	68.19
Penaeid prawns	5.1	4.19	79.35
Catfishes	4.6	4.57	96.82
Sciaenids	3.6	4.00	108.11
Elasmobranchs	3.2	2.68	79.76
Leiognathus spp	2.2	1.90	80.17
Seer fish	1.9	3.23	163.13
'Lesser sardines'	1.8	1.47	75.00
Caranx spp	1.1	0.90	76.90
Soles	1.1	1.12	99.11
'Other crustaceans'	1.0	1.70	160.38
'Other clupeids'	1.0	0.64	61.53
Thrissocles spp.	0.9	0.91	103.41
Anchoviella spp	0.8	1.38	176.92
Pomfrets	0.7	0.96	129.73
Lactarius	0.7	0.63	90.00
Ribbon fish	0.5	0.41	82.00
Perches	0.4	0.40	90.91
Chirocentrus spp	0.3	0.31	91.17
Hemirhamphus and Belone sp.	0.1	0.10	90.91

The mean, standard deviation and the percent coefficient of variation of the annual percentage distributions for all the 21 species/groups are given in Table 1.

One fact that is immediately apparent from the data (Fig. 1, Table 1) is that virtually only two fisheries make up the bulk of the landings from the coast of Karnataka, namely the mackerel and the oil sardine. Together they account for as much as 70% of the total landings. The Karnataka coast together with the neighbouring coasts witnesses the inshore migration of both the fisheries in large numbers during the post-monsoon months. Thus the availability in large numbers on the one hand and the high efficiency of the gears used (shore and purse-seines) on the other, lead to the high contribution of the total landings, in both cases. The mackerel and the oil sardine form extremely important fisheries at the national level too (Rao, 1973).

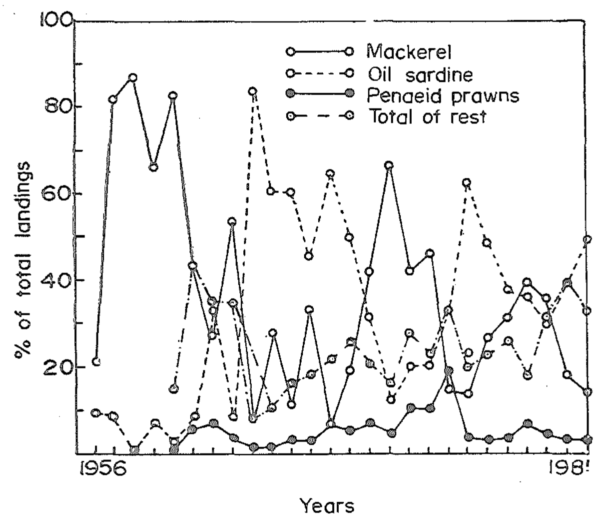

Fig. 1. Annual percentage distribution of three selected species / groups and the total of the remaining 18 spicies / groups.

It is well known that penaeid prawns being extremely coveted, are subjected to a very high fishing pressure. They constitute a fairly high proportion of the aggregate landings, though not comparable in magnitude to mackerel or sardine. In terms of bulk, few individual fisheries other than mackerel, sardine and penaeid prawns are of much significance although the sum of the remaining 18 species/groups constitute about 26% of the aggregate (Table 1, Fig. 1).

A second feature that is immediately evident is the high level of fluctuation in the annual relative composition, virtually in all the fisheries. The percent coefficient of variation (Table 1) at the minimum is 61.53 ('Other Clupeids') and the maximum value is as high as 176.92 (*Anchoviella* spp). The percentage composition of sardine ranged from as low as 0.62% in 1958 to as high as 83.75% in 1964. Similarly, the contribution of the mackerel fishery ranged from 6.93% in 1968 to 86.92% in 1958 (Fig. 1). This high fluctuation in the landings, especially in mackerel, sardine and penaeid prawns has been the woe of many a fisherman. Many authors have identified and tried to explain these fluctuations. Banerji (1964) relates the fluctuation in the catch of mackerel to the corresponding fluctuation in recruitment. Bennet (1973) provides a similar explanation for the fluctuations in the landing of the oil sardine. Yet others are of the opinion that fishery independent factors (especially oceanographic) govern the fluctuations in both mackerel and oil sardine fisheries (Murthy, 1965; Bensam, 1970; Hakkim & Dwivedi, 1977).

The apparent inverse relationship between the landings of the mackerel and oil sardine fisheries (Fig. 1) was found to be statistically significant ($p < 0.05$). The possibility of the existence of an inverse relationship between the two fisheries was earlier pointed out by Hornell (1910). According to Antony Raja (1969) the over abundant recruitment of oil sardine coupled with an excessive phytoplankton bloom in the near shore waters of the west coast in the post-monsoon months, could lead to a very high concentration of oil sardine, which is more dependent on phytoplankton than the mackerel. This sheer abundance could keep the mackerel shoals away from migrating into the inshore waters. It is possible that the present study lends some support to Antony Raja's reasoning. Until the year 1976, fishing for oil sardine and mackerel off Karnataka was by Rampani (which is a shore-seine and is hence restricted to the coastal waters). In the year 1975–76, purse-seines were introduced. This enabled fishing to be carried out in deeper waters too. The inverse relationship between the landings of the two fisheries then onwards seems less pronounced (Fig. 1) eventhough there are reversals again in the years 1980 and 1981.

The contribution of the catfish fishery as a percentage of the aggregate on an average, is a mere 4.72 (Table 1). However, there is evidence of a considerable amount of this resource off the Karnataka coast (Rao *et al.*, 1977). Increased fishing effort in deeper waters might result in increased catches.

The inshore sciaenid fishery is probably exploited fully off the Karnataka coast, as the bottom trawling in these waters is intensive. Deeper waters have to be explored in order to increase the meagre contribution of the sciaenid fishery (Table 1).

The mean relative contribution along with the standard deviation and the percent CV for all the other fisheries of Karnataka (each being relatively too minor to merit individual consideration) can be seen in Table 1.

Secular trends

The secular trends relating to the 21 species/groups and the 'Total' are given below, in descending order of their relative magnitude.

'Total': A critical appraisal of the deseasonalised data revealed the presence of an eight year cycle. In order to get at the trend this periodicity was eliminated using a 33 term (quarter) centered moving average. This moving average trend permitted a very satisfactory ($R^2 = 97$ percent) linear approximation, $\hat{Y}_t + 6748.37 + 391.96\,(t)$, which is shown in Fig. 2 (a), with $\hat{Y}_t$ in metric tonnes. It may not be difficult to find an explanation for this increasing trend over the years. The mechanisation programme, in Karnataka, and its role in increasing the State's fish production has been described in the literature (Jayaraj, 1978; Anon, 1978; Puttaswamiah, 1980). Mechanisation in Karnataka began during the second five year plan in 1957–58, when two boats were introduced. However, the number of mechanised boats soon increased very rapidly, with the introduction of purse-seiners in 1975–76, to over 1500 by the year 1978. Table 2 shows the break-up of the quantity landed by different fishing gears, for the period 1976–77 to 1980–81. As is evident, it is the mechanised craft, primarily the purse-seiners that are responsible for the tremendous increase in the total landings in recent years. Such an increase in magnitude in the total landings has been possible despite the fact that the fishing, including purse-seining, is confined to the nearshore waters. Most of the Exclusive Economic Zone is yet untapped and an increase of several fold in the total landings is probably possible if the EEZ is exploited.

Mackerel: A six-year cyclical periodicity was apparent in the deseasonalized data. This component was then isolated using a 25 term (centered) moving average of the deseasonalized data to arrive at the trend. An exponential curve $\hat{Y}_t = (3902.46\ (1.037)$ was fitted to this moving average trend (Fig. 2 b) and found to be satisfactory ($E^2 = 72\%$). This exponential rise in the landings of the mackerel can be primarily traced to the tremendous increase in fishing pressure, especially after the introduction of purse-seines in Karnataka. According to Noble (1976), the average annual catch of mackerel along the west coast is 71,595 t and the potential yield for this coast is estimated to be 73,000 t. He therefore cautions against

Table 2*. *Year-wise breakup of annual marine landings (in metric tonnes) of Karnataka*

Year	Total	Trawl nets	Purse-seines	Rampani	Other traditional gear
1976–77	62,785	15,108	10,430	30,007	7,330
1977–78	126,726	34,187	30,551	30,988	31,000
1978–79	166,995	22,690	111,788	10,686	21,831
1979–80	191,026	31,038	124,989	8,206	26,793
1980–81	160,703	38,956	96,320	5,026	20,401

*Source: Statistical Bulletin of Fisheries, 1980–81, Government of Karnataka further expansion and suggests the development of the mackerel fishery on the east coast. Shastri (1978) predicted a decrease in the mackerel catches in the near future. The present study indicates an exponentially increasing trend for the Karnataka waters. However, such a rate of production cannot be sustained for long, and the trend might reach an asymptote soon. But since this asymptote, which should be the maximum exploitable level of production, has yet to be reached and the present fishing effort for mackerel must be maintained, if not stepped up. However, just as for any other commercially exploited fishery (perhaps even more so), the mackerel fishery need to be monitored closely with an accurate picture of the effort, yield and behaviour of the fishery.

Oil Sardine: The deseasonalized data (Fig. 2 c) did not reveal any cyclical behaviour, The trend is parabolic with low curvature, which is distinctly different from the abruptly rising trend of mackerel. Fitting a second degree polynomial to the oil sardine catches of the country, Shastri (1978) found an increasing trend upto 1966 and a decline thereafter. Based on the trend in the present study and an increase in fishing pressure brought about by purse-seiners, the catches of the oil sardine off the Karnataka coast can be expected to continue the rising trend in the immediate future.

Penaeid prawns: No oscillatory movement is apparent in the deseasonalized data (Fig 2 d). It does not lend itself for any mathematical modelling either. The trend is low between 1960 and 1967, has risen from 1967 to 1974 and is uncertain from then onwards. This fishery has been subjected to a constant and very high fishing pressure Mohamed (1973), while analysing the penaeid prawn production of the country found that it increased during the period 1958 to 1967, with two major falls, one in 1963 and the other in 1965, and one peak in 1964. The year 1967 showed high catches in the east-coast. The contribution of Karnataka during the period 1958 to 1967 has been quite meagre. Ramamurthy (1978) has estimated the annual abundance along the Karnataka coast to be about 5,450 t, the potential stock 10,200 t and the maximum sustainable yield at 6,120 t. He attributes the overshooting of the MSY in 1970 to the

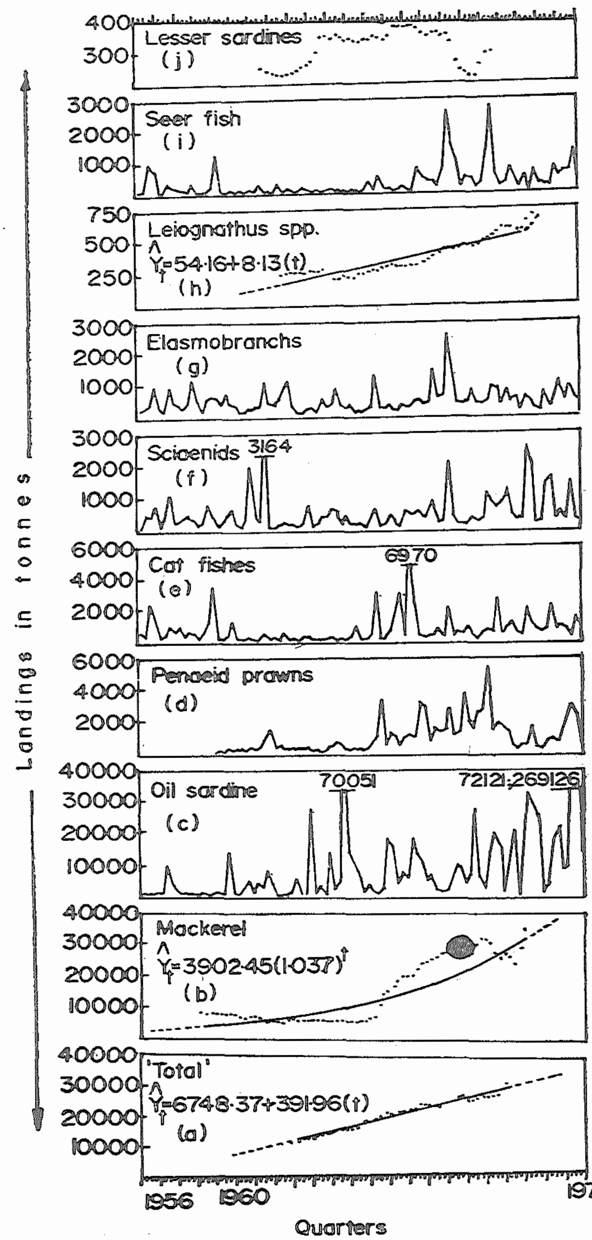

Fig. 2. Secular trends (moving average in the case of 'Lesser sardines', fitted trend functions for *Leiognathus* spp., mackerel and 'Total'; deseasonalised data elsewhere).

fact that the trawlers started fishing in September itself, instead of October. The marked decline in recent years may be due to such over-shooting of the MSY, as in 1973 and 1974. While the trend in the present study beyond 1973-74 is uncertain, it is possible that the catches are declining though there is no firm evidence yet. The trend is not continually rising despite the high intensity of effort, perhaps points to the need for some regulatory measures to be enforced, so as to check indiscriminate exploitation of juvenile prawn stocks from the nursery grounds (estuaries and backwaters)

Catfishes: Fig. 2 e shows higher catches during the late 1950's and 1960's and lower catches during the early 1960's and 1970's. In the light of these facts, a cycle of period approximately ten years was suspected, but the data available was inadequate to analyse it further. No evident trend is discernible from the data. However, a slight increase in the near future is probable. Rao *et al.* (1977) are of the opinion that the catfish resources off the south-west coast are immense and together with ribbon fish, this resource is considerably greater than the present yield of the whole country. Catfishes off the coast of Karnataka are caught along with other fishes in long- lines and gill-nets. Probably a stepping up of effort in deeper waters can result in increased catches.

Sciaenids: No oscillatory motion could be detected in the deseasonalized data (Fig 2). Regarding the secular trend, except for two probably incidental peaks in 1961 and 1962, the catches have gradually declined until 1967. From 1968 onwards, higher catches have been recorded which could perhaps be attributed to intensive trawling in recent years. Deeper waters must be explored and exploited if the trend is to show any appreciable rise.

Elasmobranchs: Fig. 2 g did not reveal any apparent periodicity. The secular trend also seems rather stagnant. According to James (1973 a) the elasmobranch catches in the east coast are almost equal in magnitude to those off the west coast, despite richer grounds on the west coast. The shark fishery off the west coast he says, is made up of large species which are by and large dependent on food fishes like sardine and mackerel, the implication being that the dynamics of the elasmobranch fishery is related to the dynamics of these food fishes. The dynamics of a fishery must be reflected in its landings so long as there is no dearth off effort. With this assumption the annual landings of elasmobranchs in this study were statistically correlated with the corresponding landings of mackerel and oil sardine. The correlation was not significant in either

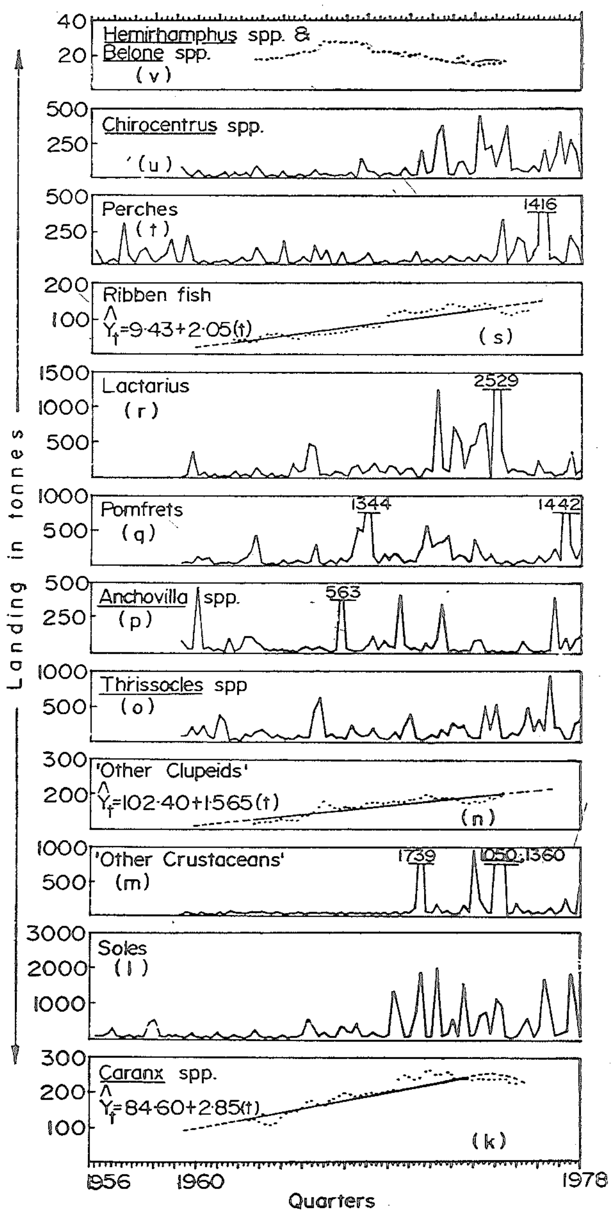

Fig 2. (Contd.) Secular trends (moving average in the case of *Hemirhanphus* spp. and *Belone* spp.; fitted trend functions for ribbon fish 'Other Clupeids' and *Caranx* spp.; deseasonalised data elsewhere).

case. The significant negative correlation has been found between the annual landings of mackerel and sardine in this study, and the fact that elasmobranchs feed on either or both fishes, the annual landings of elasmobranchs were also statistically correlated with the combined landings of mackerel and sardine. However, this too failed to produce a significant correlation. This suggest that the elasmobranch fishery off Karnataka is under-exploited, as the trends of mackerel and sardine have been rising (Fig. 2 b, c), while that of elasmobranchs has been stagnant. Moreover the west-coast has rich elasmobranch grounds (James, 1973 a)

Leiognathus spp. An assessment of the deseasonalised data revealed the presence of a six-year periodicity, which was then eliminated using a 25 term (quarter) centered moving average, to arrive at the trend. A satisfactory linear approximation $\hat{Y}_t=54.16+8.13$ (t); $R^2=85\%$ was made to the moving average trend and can be seen in Fig. 2 h. The fishery, commencing with low catches during the period of investigation, has gradually improved over the years. James (1973b) opines that since most of the species of silverbellies appear to be short-lived and since the current method of exploitation leaves enough brood for replenishing the stocks, the resources can be best utilized by catching fishes of all sizes. Silverbellies are mainly landed by the bottom trawl, and intensive fishing with this gear for prawns and other more marketable fishes seems to have resulted in the rising trend. *Leiognathus* spp. in Karnataka essentially forms an incidental fishery.

Seer fish: Fig. 2 i shows higher landings from 1967 onwards. This fishery does not seem to have reached a state of optimum exploitation and calls for further exploitation.

Lesser sardines: Since the presence of a seven year cycle was suspected, a 29 term (quarter) centered moving average was computed to eliminate the cyclical effect and give the trend (Fig. 2 j). However, the trend assumed a peculiar bell-shaped curve as can be seen in the figure. The landings of this fishery have been rather low in magnitude.

Caranx spp. The deseasonalized data revealed the presence of a six-year cycle. This periodicity was removed using a 25 term (quarter) centered moving average, and a linear approximation $Y_t - 84.60 + 2.85$ (t), fitted to the moving average trend (Fig. 2k) was found to be satisfactory ($R^2=82\%$) till 1973.T here is a gradual rise in the overall trend in this period. However, from 1973 onwards, the catches seem to have stagnated and declined slightly at the end.

Soles: No periodic movement was discernible from the deseasonalized (Fig. 2 1) data. The trend has remained stagnant till 1968 and subsequently risen. The higher catches in recent years could again be as a result of increased trawling for prawns. The fluctuations however, seem very high.

Other crustaceans.: The deseasonalized data (Fig. 2 m) showed no indication of pertiodicity. Regarding the trend, although nothing definite can be said from the deseasonalized data, the catches seem comparatively higher (with wide fluctuations) from 1971 onwards, after being almost negligible till then. This fishery includes crabs, stomatopods and lobsters. Ramamurthy (1978) opines that the combined catches of stomatopods and crabs in Karnataka are already in excess of the MSY. The lobster fishery however, according to him is capable of sustaining increased catches.

Other clupeids: A perusal of the deseasonalized data revealed the presence of a seven-year periodicity. This was eliminated using a 29 term (quarter) moving average. A linear approximation $Y_t = 102.40 + 1.565$ (t) was then satisfactorily ($R^2 = 80$ percent) fitted to the moving average (Fig. 2 n), showing an increasing trend. In fact the general trend of the fishery for the country as a whole has been on an increase, despite fluctuations (Shastri, 1978). He has fitted a fifth degree polynomial for annual data. In the present study too, the data has revealed an increasing trend. The quantity landed along the State's coastline however, is very low.

Thrissocles spp: The deseasonalized data (Fig. 2'0') did not reveal the presence of any cyclical behaviour. The trend over the years seems to be on a gradual increase, with wide fluctuations.

Anchoviella spp: The highly fluctuating deseasonalized data (Fig. 2 p) neither shows any cyclical pattern nor any definite trend over the period of investigation. Shastri (1978) however, found an overall increase in the country's anchovy fishery.

Pomfrets: The deseasonalized data (Fig. 2q) did not demonstrate any clear trend over the years nor did it reveal any cyclical periodicity. The peaks of 1968 and 1978 were assumed to be incidental. From Rao's review (1973), it is evident that the pomfret fishery of Karnataka is rather meagre, when compared to that of other maritime states, notably Gujarat. The almost constant trend noticed in the present study can perhaps be attributed to low availability of ponfrets in the nearshore waters. It remains to be seen if deep-water fishing will result in higher catches.

Lactarius: No periodicity was observed in the deseasonalized data (Fig. 2 r). The secular trend seems more or less stagnant except for a brief period of high catches during 1971–'75. This fishery is mainly landed by the bottom trawl.

Ribbon fish: Since a five-year oscillation was noticed in the deseasonalized data, 21 terms (quarter) centered moving average was computed to eliminate the periodicity and arrive at the trend. This moving average trend permitted a satisfactory ($R^2 = 86\%$) linear approximation $\hat{Y}_t = 9.43 + 2.05$ (t), as can be seen in Fig. 2 s. This fishery as in most other species/groups analysed here, has been steady, especially from the year 1969–70 (which incidentally, is also the year since when higher quantities have been landed). The general overall trend has been a gradual increase. According to James (1973 c). *Trichiurus lepturus* is the species that contributes to the bulk of the catch all over the country. He is of the opinion that this fish which moves in great shoals and apparently migrates from the east coast to the west coast during the period August–October, could be caught "to any extent possible" without affecting future stocks, since the fishery then is supported by spent fishes. The catches off the coast of Karnataka however, are quite meagre.

Perches: From the deseasonalized data (Fig. 2 t), the absence of any periodic movement is evident. The secular trend also seems stagnant over the years except for one isolated peak in the year 1977.

Chirocentrus spp: The deseasonalized data did not reveal any periodic movements (Fig. 2 u). The trend, just as in the case of soles (Fig. 2 1), has risen from 1970 onward after keeping to an almost uniform low until then. It may be pointed out here that according to Luther (1973) the dorab catch could be stepped up in each of the States landing low quantities, since this resource is available in appreciable quantities along both the coasts.

Hemirhamphus spp. and *Belone* spp: Since the deseasonalized data revealed the presence of a seven-year oscillation, this periodicity was eliminated by means of a 29 term (quarter) contered moving average so as to arrive at the trend, which was found to be decreasing (Fig. 2 v).

The present study has shown that out of the 21 fisheries studied, there is an unambiguous decreasing trend in combined landings of *Hemirhamphus* spp. and *Belone* spp; comprising only 0.1% of the annual landings. The landings of penaeid prawns and *Caranx* spp. while demonstrating increasing trends initially seem to have decreased towards the end of the period of study, but there is no firm evidence of a decreasing trend in either case. These two fisheries together average about 6% of the annual landings. Of the remaining 19 fisheries, more or less stagnant trends are noticed in 13 comprising about 21% of the annual landings. Clearly increasing trends have been found in mackerel, oil sardine, *Leiognathus* spp. 'Other clupeids' and ribbon fishes. These five fisheries however, comprise almost 73% of the annual landings on an average. Consequently a clearly rising trend is seen in the case of 'Total' too.

Given the isolated trend of a fishery over more than twenty years, it is possible to reach a few conclusions regarding the state of the fishery. The above facts seem to call for an increase in fishing effort, even in the currently exploited fishing grounds, at least in the case of those fisheries that have demonstrated increasing trends. Regarding the fisheries with stagnant trends too, an increase in effort should throw some light on not only the availability but also the capacity of the fishery to sustain reductions due to fishing. The results also seem to indicate that it might be necessary to introduce some regulations in fishing for penaeid prawns, *Caranx* spp. and *Hemirhamphus* spp. and *Belone* spp.

In any case it is essential to continually monitor the dynamics of each and every commercially exploited fishery based on sufficient and reliable data on the fishing effort, catch-statistics, life-history, spawning, recruitment, food and feeding habits and behaviour. Appropriate and feasible regulations will have to be introduced as and when the trends show signs of decline. Most fish resources in the Indian seas as yet remain under-studied when compared to those in the Atlantic and Pacific waters. More work needs to be done on the various relevant aspects in order to better the accuracy of counselling in fishery management.

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